ERDC/CERL TR-03-24

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November 2003

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Final Report



Prepared for U.S. Army Corps of Engineers
Washington, DC  20314-1000

Under Work Unit CNN-T081#

**ABSTRACT:** The purpose of the Land Condition Trend Analysis (LCTA) program at the Marine Air Ground Task Force Training Command (MAGTFTC), Twentynine Palms, California, is to support natural resource management decision making. The LCTA monitoring program collects the data necessary to (1) determine effects of military activity on both the current ecological condition of MAGTFTC and the trend in this condition, (2) help characterize the relationship between military impacts and the type, location, timing, intensity, and duration of training, and (3) characterize plant communities on MAGTFTC. This report assesses the strengths and weaknesses of the current LCTA program and offers recommendations for improvements.

The current LCTA Protocol meets its primary purpose by addressing the effect of training on the bajada areas of MAGTFTC and providing information for management of this type of site. Albeit a secondary purpose, the Protocol inadequately samples the variability in the overall vegetation of MAGTFTC and is weak for evaluating ecological responses to stressors other than training and all stressors in areas other than the bajadas. Two of the data collection methods used in the Protocol — line transects and belt transects — are useful and efficient and should be retained. Other sampling methods and the variables they quantify may merit review and discontinuance. While current requirements and funding levels will continue to drive the sampling, the Protocol would benefit from fewer variables — but more locations — being sampled. The data collected from 1997 to 1999 provide a useful baseline data set for a large portion of MAGTFTC. However, a number of areas were under-sampled or not sampled at all. The data analyses performed are adequate for some uses, but are inadequate for others.

In summary, the MAGTFTC LCTA Protocol has resulted in a valuable initial data set, especially for the evaluation of training impacts on a selected area of the installation, but the plant communities over the entire installation need better sampling distribution. The complexity of the sampling can be reduced without adversely affecting the results. The analyses and reporting of the results of the data collection from 1997 to 1999 would be greatly strengthened by the inclusion of more direct statistical comparisons and increased quality control during data collection. The overall program is good and the full value of the LCTA program will increase with each year of data collection, which will, in turn, pay dividends in its value to management decision making.

# Contents

# Preface

This study was conducted for the Office of the Directorate of Environmental Programs (DAIM), Assistant Chief of Staff for Installation Management (ACSIM) under project 622720896, “Environmental Quality Technology”; Work Unit CNN-T081. The technical monitor was Dr. Vic Diersing, DAIM-ED-N.

The work was performed under the direction of the Ecological Processes Branch (CN-N) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL), and the Ecological Resources Branch (EE-E) of the Ecosystem Evaluation and Engineering Division (EE) of the Environmental Laboratory (EL). The CERL Principal Investigator was Jeffrey S. Fehmi. The EL Principal Investigator was Dr. David Price. The manager at the Marine Air Ground Task Force Training Command (MAGTFTC) was Rhys M. Evans. The work was performed by Terry McLendon and W. Michael Childress with MWH, Fort Collins, CO under DACA88-99-D0004. The technical editor was Gloria J. Wienke, Information Technology Laboratory. Stephen Hodapp is Chief, CN-N, and Dr. John T. Bandy is Chief, CN. The associated Technical Director was Dr. William D. Severinghaus, CC-T. The Director of CERL is Dr. Alan W. Moore.

CERL and EL are elements of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL James R. Rowan, EN, and the Director of ERDC is Dr. James R. Houston.

# 1 Introduction

## Background

The U.S. Department of Defense is responsible for managing over 25 million acres (10 million hectares, or 100,000 sq km) of land and uses a variety of programs to periodically assess land condition. The Land Condition Trend Analysis (LCTA) program is in wide use and is based on standard methods to collect and analyze natural resources data. Because this is a national level program, the standardized methods may not represent the optimum procedure at any specific location. Periodic review of the program and its results are needed to ensure the continued best use of funding and manpower resources as well as ensuring that the natural resources are being measured in a way that meets the requirements of the installation.

The Marine Air Ground Task Force Training Command (MAGTFTC) located at Twentynine Palms, CA, comprises 596,480 acres (about 241,400 hectares or 2,414 sq km) in the Mojave Desert, 40 miles (about 64 km) northeast of Palm Springs (Howard et al. 2000). Established in 1952, the primary mission of MAGTFTC is to develop, administer, and evaluate the Marine Corps' Combined Arms Exercise training. The responsibility for accomplishing the Marine Corps training mission while providing good stewardship of the desert ecosystems of MAGTFTC presents a significant management challenge. To meet this challenge, MAGTFTC has applied a program to monitor and predict impacts on these training lands. The purpose of the monitoring program is to provide lands for safe and effective training and provide the information needed to maintain the ecological integrity of these Mojave Desert ecosystems. The requirements for monitoring are threefold. They include the need to determine which parts of the land have added or diminished capacity to sustain training without environmental degradation, the assessment of invasive or problem plant species, and the status of endangered species or their habitat.

A primary component of the monitoring effort at MAGTFTC is the LCTA program. The purpose of the LCTA program on MAGTFTC, Twentynine Palms is to support natural resource management decsionmaking. The program involves two primary components: (1) long-term monitoring field studies and (2) a Land Use Compatibility (LUC) Model (Tierra Data Systems 2000). The purpose of the monitoring component is to collect the data necessary to: (1) determine effects of military activity on both the current ecological condition of MAGTFTC and the trend in this condition, (2) help characterize the relationship between military impacts and the type, location, timing, intensity, and duration of training, and (3) characterize plant communities on MAGTFTC (Tierra Data Systems 2000).

This report provides the results of an evaluation of the LCTA Protocol and recommendations for improvements. This is part of the peer review of monitoring and reports recommended in the *LCTA II Technical Reference Manual* (Army Environmental Center 1999).

## Objective

The objective of this research was to evaluate the LCTA Protocol at MAGTFTC and recommend changes for adding value to or improving the Protocol.

## Approach

The LCTA program at MAGTFTC was evaluated by reviewing each step of the current process. Strengths and weaknesses assessed were for landscape characterization, study design, plot establishment, field measurements, data quality, and data analysis. Recommendations were generated for sampling and monitoring design, data collection, and data analysis and reporting.

## Mode of Technology Transfer

This analysis and data have already been provided to MAGTFTC. Other installations can use this information to evaluate their LCTA programs.

This report will be made accessible through the World Wide Web (WWW) at URL:

http://www.cecer.army.mil

# 2 Assessment of Current LCTA Protocol and Data

## Description of LCTA Protocol

The current LCTA Protocol is described by Tierra Data Systems (2000). This Protocol consists of five components: (1) landscape characterization, (2) study design, (3) plot establishment, (4) field measurements, and (5) data analysis.

### *Landscape Characterization*

A multilevel classification was used to characterize the landscape. The area was first divided into geologic types, which were then divided into four landforms (dry wash, playa, bajada, mountains). The bajada landform was further divided by substrate (sandy, coarse sand, rocky, pavement). One further classification type was applied to all land forms: training impact. The seven categories of training impact were: developed, very high, high, medium, low, very low, and none.

### *Study Design*

The stated primary consideration in the selection of the study design was to maximize the statistical ability to draw inferences relative to variability of the landscape and training usage (Tierra Data Systems 2000:3-4). The design specifically emphasized "use gradients" on the bajadas. Mountains and washes were sampled, but intensity of use was not well captured for these landforms.

The study design was developed to measure the effects of two primary parameters: (1) intensity of training use and (2) changes in vegetation and soils over time. Disturbance gradients and reference areas were used to measure the impacts of training. Disturbance gradients were sampled by placing three to four plots within the same vegetation type and soil type, and within a similar topographic position, but with each plot having different training impact. In addition, 21 reference plots were established in areas that appeared to have relatively little surface disturbance. Fifteen of these were within MAGTFTC and six were in the Cleghorn Lakes Wilderness Area, which is adjacent to MAGTFTC on Bureau of Land Management (BLM) lands.

Two plot sampling methods were used to sample temporal changes. The first method was used to establish and sample 76 LCTA plots over a 3-year period (1997-1999). Sixteen additional LCTA plots were added in 1998 in areas where training intensity changed during the sampling period. These areas apparently received a lower intensity of training prior to 1998, after which training intensity increased. Sampling was in 1998 and 1999. The third method was to compare aerial photographs from 1953 to photographs from 1990 for five sites for which data were available. At each site, densities of larger shrubs were counted from the photographs and the densities compared between years.

### Plot Establishment

The basic plot design used rectangular plots (belt transects; Daubenmire 1968; Stoddart et al. 1975), 4 m wide and 100 m long. A complete data set was collected at each of the 76 LCTA plots in 1997, the 16 new plots in 1998, and all 92 plots in 1999. A reduced number of variables was sampled in 1998 on the 72 plots established in 1997.

### Field Measurements

The variables chosen for sampling were selected to measure overall site condition and quality. In particular, they were to sample surface stability, erosion, plant community, and nutrient cycling. The following 13 variables were measured:

1. training impact,
2. number of vehicle tracks,
3. plant cover, by species (line intercept measurements and cover class estimates),
4. species list (belt transect),
5. frequency by lifeform,
6. density of shrubs (belt transect),
7. density of ant burrows (belt transect),
8. density of animal burrows (belt transect),
9. soil microbial biomass,
10. rockiness of soil surface,
11. estimated rock volume,

12. soil chemistry (pH, EC [electrical conductivity], nitrate-N, P [phosphorus], K [potassium]), and
13. soil texture.

### *Data Analysis*

Cover and density data were analyzed using linear regression, regressing cover or density (y-variable) against disturbance intensity (x-variable). There was also some limited use of analysis of variance (ANOVA).

## Evaluation of LCTA Protocol

Tierra Data Systems (2000:1-1) stated that there were three objectives to the monitoring component of the LCTA program at MAGTFTC: (1) determine the effects of military activity on the current ecological condition at MAGTFTC and the trend in this condition, (2) provide data to help characterize the relationship between military impacts and the type, location, timing, intensity, and duration of training, and (3) characterize plant communities on MAGTFTC. The current LCTA Protocol primarily addresses the first two objectives. The third objective, to characterize the plant communities on MAGTFTC, is only weakly addressed.

### *Landscape Characterization*

The first step in the current LCTA Protocol, similar to most monitoring designs, is to define the units of classification. The Protocol classification starts with geologic types, adds landforms, and then training impact. Training is concentrated on the bajadas, with little impact higher up on the slopes. This is a logical classification system to document current training impacts. However, this system is weak for characterizing the plant communities of MAGTFTC (the third primary objective), and especially weak to document the dynamics of these communities.

Geology, topography, and surface disturbance certainly influence vegetation. However, they do not entirely define the distribution of plant communities. A more traditional approach to establishing an initial classification system for MAGTFTC would be to produce a vegetation map of the installation using aerial or satellite photographs, with appropriate ground truthing.

A plant community map for MAGTFTC is presented in Tierra Data Systems (2000), with 15 communities listed. This appears to be a more balanced basis for a classification system than the one used in the Protocol. Perhaps a practical classification system would include the vegetation and the ecosite classifications presented by Tierra Data Systems (2000). The ecosites are basically soil types, modified for topography. Superimposing the vegetation types on the ecosite map should give a good basis for a monitoring classification system because it would include both plant communities and those physical characteristics, such as soil texture and topography, that are important in training land management. Development of such a classification system should be relatively easy and inexpensive, since both GIS layers are currently available. The only additional work would be some ground truthing and a determination, preferably with a statistical component, of significant classification types.

### *Study Design*

The primary consideration in the development of the study design was to maximize statistical power (Tierra Data Systems 2000). The stated approach was to maximize sample size (replications) by sampling more sites, rather than using the available resources (e.g., manpower and funds) to sample more variables at fewer sites. This can be a very constructive approach. With the normal distribution and equal variance, an increase in sample size will increase the power of the statistical tests (Snedecor and Cochran 1989:52, McLendon 1995).

However, another important concept in vegetation sampling is that the spatial distribution of the samples must be sufficient to adequately sample the spatial distribution of the vegetation, at whatever level of interest may be defined by the goals and objectives of the sampling program. The Protocol utilizes 92 plots to sample an area of almost 600,000 acres, so each plot represents almost 6500 acres (about 26 sq km) of the total area. Although it may be true that there is relatively little variation in the vegetation within 6500 acres of a creosotebush flat, a great deal of ecological variability is likely to occur on 6500 acres of desert mountains or upper washes, and probably on 6500 acres of bajada.

A comparison of the study plot map (Tierra Data Systems 2000, Map 4-4) and the plant community map (Tierra Data Systems 2000, Map 2-4) suggests that a number of the 15 plant communities are not sampled at all, and some of these are very important for management of designated critical habitat at MAGTFTC. The Joshua Tree Woodland, Mesquite Thicket, Dune Creosotebush Scrub, Sweetbush/Cheesebush, and Mojave Yucca Scrub communities do not appear to be sampled at all, and the Saltbush Scrub is sampled only in one small area. Sampling a plant community in only one isolated area of its distribution on a landscape is likely to result in misrepresentation of the parameters sampled. The Catclaw/Desert Willow community is a critical community in the Mojave Desert. Yet it does not appear that it is included in any of the 92 LCTA locations.

The LCTA monitoring program is well designed to monitor impacts of training activities on the bajadas. However, for characterizing and documenting the changes in MAGTFTC plant communities, the Protocol could be substantially improved by including more of the plant communities.

### *Plot Establishment*

The selection of a belt transect as the basic sampling unit is reasonable and appropriate. The belt transect allows for measurements of variables requiring area (e.g., density), while also allowing line transect data to be collected.

The size of the plots (4 m x 100 m) was a good initial choice, but this may be an area with the potential for reduction in effort. In many ecosystems, including deserts, it often more efficient to use a larger number of smaller transects. A shorter length (i.e., less than 100 m) transect may be adequate for points added to this sampling program in the future. The optimum size may be determined by evaluation of the existing data.

### *Field Measurements*

The variables sampled were chosen because they were believed to be good measurements of overall site condition and quality. A wide variety of variables were sampled, each variable contributing to a better understanding of the ecology of the landscape.

The measurement technique for plant disturbance cover appears to be reasonable and practical. The use of the line-intercept method for recording plant cover and belt transects for measuring shrub density are widely accepted (Oosting 1956, Daubenmire 1968, Bonham 1989, McLendon 1995). Counting ant mounds and animal burrows can be done easily using the belt transects.

The nested frequency counts do not seem to add information proportionate to the amount of effort required for their collection. The exception would be the measurement of litter and biological crusts, both of which could be effectively measured using the same line transects that are used to measure species cover.

The measurement of soil microbial variables is an attempt to sample an important ecological component. However, the adequacy of this sampling procedure is questionable. Soil microbial activity, even in a single location, varies significantly on short temporal scales, in response to such factors as season, temperature, and moisture conditions. For this sampling to be effective, the samples from all the plots must be collected within a short period of time to minimize the temporal variation within any single sampling year. In addition, care should be taken to evaluate annual differences because the samples could have been collected under very different conditions (e.g., wet period in one year, dry period in another), and the results might be attributed to some other factor (e.g., training). As it stands, it is difficult to see the value in continuing this sampling. The samples do not seem to be readily comparable because of the volatile biology of these organisms. If continued, the samples should be collected on a contiguous sampling period of no more than a few days, or even on a single day if possible.

The measurements of soil rockiness may provide some information about aeolian processes but this measure seems unlikely to be quantitative and sensitive enough to be of substantive use. The sampling of the soil chemical and physical factors should provide very interesting data, but these data can become expensive to collect. Therefore, it should be made clear how important this type of data is to the objectives of the monitoring program. If these data are important to meeting the objectives of the program, sampling may be justified. If, however, these data are not critical to meeting the objectives of the program, their collection should be discontinued or limited to a sub-sample of the existing sample points.

### *Data Analysis*

Regression analysis (Draper and Smith 1966; Snedecor and Cochran 1989) is an appropriate method for analyzing the relationship between disturbance intensity and the cover and density measurements. However, other statistical methods will be required to analyze the other types of data.

The most useful methods for analyzing spatial and temporal dynamics of vegetation are multivariate statistics. Principal component analysis and stepwise discriminant analysis (Seal 1964; Overall and Klett 1972; Lachenbruch 1975) are also useful tools to classify vegetation and evaluate changes over time, either disturbance induced or as the result of successional dynamics (Matthews 1979; McLendon and Dahl 1983; McLendon and Redente 1990, 1991). These multivariate techniques have been used to classify and describe the vegetation, and analyze changes in vegetation over time, at five military installations using LCTA data (McLendon et al. 1996). They could be easily applied to the existing data set at MAGTFTC.

## Assessment of LCTA Data

### *Disturbance Mapping*

The disturbance maps produced by Tierra Data Systems (2000) were based on aerial photograph interpretations, comparing 1953 and 1990 photographs. Disturbance intensity was classified as one of seven categories, based on visual estimation of the photographs. Data collected in this way is valuable because few other historical information sources may be available.

The comparisons indicate a dramatic increase in disturbance over the 37 years. However, one should be cautious about placing undue confidence in this comparison. The comparison is dependent on the ability of researchers to distinguish subtle differences on aerial photographs, the quality of which differed substantially between dates, and to relate these subtle differences to the seven categories. Seven categories may be too many to accurately distinguish. Three or four may increase the accuracy of the classification, because classification accuracy increases as the number of categories decreases. Perhaps the maps should indicate only (1) development, (2) heavy disturbance, (3) intermediate disturbance, and (4) light disturbance.

### *Plot Results*

Plot results are presented on the basis of disturbance, i.e., mean values for disturbance levels on the bajadas, with corresponding reference site values. This captures the training disturbance quite well. The data for plant communities should also be reported.

The plot data refer only to general lifeform categories (e.g., large shrubs, small shrubs, herbaceous perennials). This is useful for characterizing general vegetation aspects, but it ignores species composition. This approach is uncommon for reporting changes in vegetation. Species differences are critical in understanding vegetation dynamics, plant succession, and ecosystem health. The need to simplify a complex data set is understandable, and lifeform groupings are appropriate for this. However, quantitative responses by major species should also be presented.

The data presentation (Table 4-3, Tierra Data Systems 2000) contains a number of numeric, sampling, and statistical shortcomings. First, four basic types of comparisons are presented: (1) comparisons among bajada landforms, (2) comparisons among disturbance intensities, (3) comparisons over time, and (4) comparisons between disturbed and reference areas. No statistical indicators of significance (e.g., standard errors) are presented. Therefore, it is not possible to determine how much of the differences in the values being compared are the result of the factor indicated and how much are the result of statistical error. For example, cover of large shrubs on lightly disturbed rocky bajadas was reported to average 3.05 percent in 1997, compared to 3.60 percent in 1999. The data suggest that large shrubs are increasing on lightly disturbed rocky bajadas, but it cannot be determined from the report if there is any statistical difference between the means of 3.05 and 3.60. Similarly, the 2.75 mean on moderately disturbed rocky bajadas may not be statistically different from the 2.10 mean on coarse bajadas. More tables should be used to present these data, with more statistical information presented with the means.

A second shortcoming in Table 4-3 is that there is no consistency in reporting significant decimals. Some values are reported with no decimal (e.g., 19). Other values are reported to one or two decimal places (e.g., 0.8 and 0.85). If the data were collected in such a way that the most significant digit was units, then 0.8 and 0.85 should have been reported as 1. However, if two decimal places were significant, then 19 should have been reported as 19.00 and 0.8 as 0.80. These differences become very important in determining the usefulness of the data set, and in most natural resources literature the number of digits indicates the accuracy of the estimate.

Third, the presentation of the data implies that the values on the disturbed sites should be compared to those on the reference areas. However, the BLM reference data was for 1998 and there was no corresponding 1998 data for the disturbance areas. This seems important because there was a substantial amount of variation between 1997 and 1999 data for some of the variables. For example, large shrub cover more than doubled on the coarse bajadas between 1997 and 1999, and it increased on the pavement bajadas from 0.00 in 1997 to 2.50 percent in 1999. These are substantial temporal increases for large shrubs. Because only 1 year of data was collected on the BLM reference areas, it is not possible to determine an equivalent temporal variation for these reference areas. Therefore, it is difficult to compare these reference area values to the disturbed area values.

A further problem is that data are not presented in a manner suitable to be used to evaluate the compatibility between the reference and disturbed areas. This is a fundamental requirement in the selection of reference areas. It should be established that the reference area is indeed a valid reference area for comparison with an impacted area. The data presented in Table 4-3 does not establish this validity, because of the wide differences in values reported for different reference areas that are supposed to relate to the same disturbed area. For example, two reference areas are listed for the rocky bajada. The reference area designated “HAB” had no large shrubs in 1997 or 1999. The BLM reference area had a mean of 8.75 percent in 1998. These could be argued to be different plant communities, if one area had no large shrubs and the other had nearly 9 percent large shrubs. The respective value on the lightly disturbed rocky bajadas was 3 to 4 percent, intermediate between the two reference areas. The mean of the heavily disturbed rocky bajadas was 1 percent, a value greater than on one of the reference areas. This suggests that either (1) the HAB reference area is more heavily disturbed than the heaviest disturbed rocky bajadas or (2) the HAB reference area may not be the best reference area for the rocky bajadas. Similar comparisons can be made with the coarse bajada reference areas and with most of the other variables.

In summary, four primary shortcomings are apparent in the reported plot results. First, little data are presented relative to the plant communities at MAGTFTC. Rather, the effort is highly focused on evaluating training impacts. Second, the reference areas may be poorly matched with the disturbed areas because insufficient data are presented to make comparisons among them. Third, no statistical parameters, other than the means, are provided. Therefore, no estimates of significance in the differences among means can be made. Variability among the means is substantial. Differences among means that might be attributed to disturbance intensity, site differences, or temporal changes, cannot be separated from sampling error. This weakens the data set. Finally, the values reported vary as to significant digits, which again makes numerical comparisons difficult.

### *Trend Analysis*

Trend was measured by comparing shrub cover and density values in 1997 to the respective values in 1999, using t-tests to determine statistical significance.

There were 22 comparisons made for cover and 39 comparisons for density. Although the trend analysis is stated to be for shrubs, the cover data includes a perennial grass and the density data includes two grass and three animal variables.

Sample size varied among these 61 variables, ranging from 3 to 80. There were 92 plots. All plots would not be expected to contain all species. However, the sample size for all shrubs (74 for cover and 80 for density) indicates that a relatively large number of plots have no shrubs. The text does not include the methods used to establish the sample size for a particular variable, which makes the information difficult to use. The method should be included in any future report of any kind. Two years (1997 to 1999) is a very short length of time to attempt to establish trends in vegetation dynamics. However, this is the length of time associated with the available data.

The use of t-tests to test the significance of differences between two means is a commonly used and widely accepted method (Snedecor and Cochran 1989; Bonham 1989; McLendon 1995). However, two factors should be addressed in such applications. First, the t-test assumes a t distribution (related to the normal distribution) of the data. Many biological variables fit the normal distribution fairly well, but some do not. When a t-test is applied to those that do not, the probability estimates associated with the t statistic are incorrect. The farther the distribution is from the t-distribution, the poorer the fit with the t-statistic. There is no indication that the distributions of the 61 variables compared in Tables 4-9 and 4-10 were checked to see if the distribution met the assumptions for the t-test.

The second factor that should be considered is that the significance level used in a t-test (or any parametric method) is based on a selected probability level. Two significance levels are stated for Table 4-9: 0.10 and 0.05. However, no indicators of significance (* for 0.10 and ** for 0.05) are listed in Table 4-9. The specific probability values are given in Table 4-10. A total of 61 variables were tested using the t-test, resulting in 61 t-tests. At the 0.10 level, 6 of these would appear significant when in fact they were not significantly different. At the 0.05 level, there would be 3 “false positives.” At the 0.05 level, 5 of the 22 cover variables had significantly different means. This appears to be a reasonable number because only 1 would be expected based on chance. Fourteen of the 31 density variables were indicated to have significantly different means (0.05). One or two of these may have been by chance. A correction factor (the Bonferroni correction) is available to adjust for this effect.

Of the 20 species whose cover values were tested, 9 increased in live individuals and 5 decreased; 5 increased in dead individuals and 1 decreased. Overall, both live and dead shrubs increased. Of the five statistically significant responses, all were increases (three for live plants and two for dead plants). There is no apparent ecological explanation for distinguishing the species that increased from those that decreased. This suggests that these trends are more the result of sampling variability than true ecological responses. However, the responses are very short-term responses, and this short time period certainly affects the response patterns.

Of the 17 significant changes in mean density, 16 increased and 1 (dead shrubs, all species) decreased. Four of the variables had very large increases, three of which were for mature plants (5-fold, 8-fold, 14-fold). These are surprisingly large increases for mature shrubs over a 2-year period. They again may indicate sampling variability rather than true ecological variability. However, the variables were for densities that should have been relatively easy to accurately record within the belt transects.

# 3 Recommendations for Improving the LCTA Protocol

The recommendations for improving the LCTA Protocol are divided into three sections: (1) sampling and monitoring design, (2) data collection, and (3) data analysis and reporting.

## Sampling and Monitoring Design

The current LCTA Protocol includes a reasonable and appropriate design for sampling the effects of training activities on the primary training areas and monitoring the trends on these sites. The basic design of 92 plots, arranged in clusters with the within-cluster plots varying by disturbance intensity should be retained, but with some additions. Recommendations on the type of sampling conducted at these plots are in the next section (Data Collection).

The major weakness in the Protocol is that it inadequately samples the variability in the overall vegetation of MAGTFTC and is weak for evaluating ecological responses to stressors other than training and all stressors in areas other than the bajadas. Areas receiving substantial training activities are well-sampled. Areas not receiving high training activities are poorly sampled. A three-part plan to address this weakness follows.

First, an ecological type map should be developed for MAGTFTC. The existing plant communities and ecosite GIS layers can be combined to form an initial ecological type map. The resulting ecological units should then be refined using the most recent aerial photographs. This refined map should then be ground-truthed to establish actual boundaries and to make a preliminary inventory of the vegetation.

A preliminary classification of the vegetation of MAGTFTC should be conducted using multivariate statistical techniques and all existing vegetation data (McLendon and Dahl 1983). This classification system would then be used to determine which of the ecological mapping units should be retained and which should be combined. The result of this effort would be a preliminary classification of the vegetation of MAGTFTC and a corresponding vegetation map.

A minimum of three study plots should be located within each of the mapping units from the vegetation map. It is anticipated that the vegetation map will include 20 to 30 vegetation types, and there will probably be an average of 5 unique locations per vegetation type. This will result in 100 to 150 mapping units. Any of the 92 plots from the current LCTA design that are located within a respective mapping unit on the new vegetation map can be used instead of establishing a new plot. All newly established plots should be randomly located within their respective mapping unit.

Data collected from these plots can be used to (1) test the validity of the initial vegetation classification system, (2) determine the adequacy of the number of plots per plant community, and (3) monitor vegetation changes throughout MAGTFTC.

## Data Collection

It may be possible to reduce the amount of data collected and still meet the sampling objectives. The following sampling should be continued using the same techniques that are described by Tierra Data Systems (2000): (1) disturbance cover, (2) line-intercept (by species, but to also include bare ground, litter, and biological crusts), (3) shrub, ant mound, and animal burrow densities in the belt transect, and (4) available soil nitrogen (but include both nitrate and ammonium).

Each of these variables should be sampled at each plot on an annual basis for a minimum of 5 years. This will establish patterns of annual variation and provide a baseline for future efforts. Analysis of these data can then be used to determine the most efficient sampling frequency (e.g., every 3 years). As long-term data become available, sampling frequency can be adjusted.

The standard plot design is currently 4 m x 100 m. This is probably larger than necessary for the new plots. A smaller plot will take less time to sample, thereby reducing the resource requirements for the increased monitoring effort. A 4 m x 40 m plot is probably adequate. However, a meter-by-meter analysis of the existing LCTA line transect data should provide an excellent means for establishing the most effective length. This analysis can be conducted relatively quickly and inexpensively.

If the size of the existing plots is changed, some of the data previously collected will not be directly comparable. In particular, the density data will not be directly comparable and the line transect data will need to be adjusted to account for a shorter distance being included. Therefore, we recommend that the size of the existing plots be maintained to keep data consistency, even though a shorter transect would adequately sample the variables. In this manner, the density data and the line transect data can be compared directly with the data collected in 1997-1999. In addition, density and line transect data can also be recorded within these plots in the smaller sizes of the other transects, with little additional effort (e.g., count the number of shrubs in the belt transect, recording the data in two parts, one corresponding to the smaller plot area and the other corresponding to the rest of the plot, the sum of the two then equaling the size of the original plots).

The recommended expanded sample design would significantly increase the number of plots to be sampled (300 to 500). However, the time spent at each plot will be significantly reduced because of fewer variables being sampled. In addition, the most expensive and time-consuming variables (soil microbial analyses, soil chemical analyses) would be eliminated, which may allow the change without an overall increase in costs.

## Data Analysis and Reporting

### *Data Analysis*

Simple univariate statistics should be included for all variables, including all species. These statistics include: means, standard deviations, and 95% confidence intervals of the means. These should be calculated for each site, each plant community, and overall, for each sampling year. Where appropriate (based on statistical distributions and type of comparisons), t-tests and paired t-tests should be used to provide tests for simple two-factor comparisons.

Regression analysis is a reasonable and acceptable method of analyzing the disturbance intensity data. However, more extensive applications should be conducted. Regressions should be conducted on cover and density data for all lifeforms and on the major species.

Multivariate statistical analyses (e.g., principal components and stepwise discriminant analyses) should be conducted on the data set each year. Initially, the techniques can be used to classify the vegetation and characterize the vegetation types and their relationships to each other. Over time, the techniques can be used to analyze temporal changes (e.g., disturbance effects, secondary succession).

### *Data Reporting*

A strong Quality Assurance/Quality Control procedure should be implemented. All field data should be entered into an electronic database as soon as possible after collection. Four- or six-letter codes for species names can be used, but it is critical that a legend be provided with the proper scientific name associated with each code. The process of entering the data and verifying the nomenclature should be completed before the field crew that collects the data leaves the installation. This would ensure that any questions about species identifications are resolved.

Files should be created that provide easy-to-read listings of all data by plot. Tables should be created that present these data by variable, by species, by plot, and by year. In reports, these would normally be included as appendices.

Summary tables in reports should be easy to read, correct relative to significant digits, and presented in a logical sequence. A large amount of data has already been collected at MAGTFTC, and more will likely be collected in the future. However, if the data are not available, they are not of much use. It might be advisable to contract out the responsibility of summarizing the data each year. Among other things, this would provide an annual review of the status of the program, along with the status of the database.

# 4 Conclusions

The purpose of the LCTA program on the MAGTFTC, Twentynine Palms, CA, is to support natural resource management decision making. The LCTA monitoring program collects the data necessary to (1) determine effects of military activity on both the current ecological condition of MAGTFTC and the trend in this condition, (2) help characterize the relationship between military impacts and the type, location, timing, intensity, and duration of training, and (3) characterize plant communities on MAGTFTC.

The current LCTA Protocol meets its primary purpose by addressing the effect of training on the bajada areas of MAGTFTC and providing information for management of this type of site. Albeit a secondary purpose, the Protocol inadequately samples the variability in the overall vegetation of MAGTFTC and is weak for evaluating ecological responses to stressors other than training and all stressors in areas other than the bajadas. Two of the data collection methods used in the Protocol — line transects and belt transects — are useful and efficient and should be retained. Other sampling methods and the variables they quantify may merit review and discontinuance. While current requirements and funding levels will continue to drive the sampling, the Protocol would benefit from fewer variables — but more locations — being sampled. The data collected from 1997 to 1999 provide a useful baseline data set for a large portion of MAGTFTC. However, a number of areas were under-sampled or not sampled at all. The data analyses performed are adequate for some uses, but are inadequate for others.

In summary, the MAGTFTC LCTA Protocol has resulted in a valuable initial data set, especially for the evaluation of training impacts on a selected area of the installation, but the plant communities over the entire installation need better sampling distribution. The complexity of the sampling can be reduced without adversely affecting the results. The analyses and reporting of the results of the data collection from 1997 to 1999 would be greatly strengthened by the inclusion of more direct statistical comparisons and increased quality control during data collection. The overall program is good and the full value of the LCTA program will increase with each year of data collection, which will, in turn, pay dividends in its value to management decision making.

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# REPORT DOCUMENTATION PAGE

*Form Approved OMB No. 0704-0188*



**1. REPORT DATE (DD-MM-YYYY)** 11-2003

**2. REPORT TYPE** Final

**3. DATES COVERED (From - To)**

**4. TITLE AND SUBTITLE**
Assessment and Application of the LCTA Protocol at MAGTFTC, Twentynine Palms, California

**5a. CONTRACT NUMBER**

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**6. AUTHOR(S)**
Terry McLendon, W. Michael Childress, Jeffrey S. Fehmi, and Rhys M. Evans

**5d. PROJECT NUMBER**
622720A896

**5e. TASK NUMBER**
CNN-T081

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
PO Box 9005
Champaign, IL 61826-9005

**8. PERFORMING ORGANIZATION REPORT NUMBER**
ERDC/CERL TR-03-24

**9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
Department of the Army
Office of the Director of Environmental Programs
600 Army Pentagon
Washington, DC 20310-0600

**10. SPONSOR/MONITOR'S ACRONYM(S)**
DAIM-ED-N

**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

**12. DISTRIBUTION / AVAILABILITY STATEMENT**
Approved for public release; distribution is unlimited.

**13. SUPPLEMENTARY NOTES**
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

**14. ABSTRACT**
The Land Condition Trend Analysis (LCTA) program at the Marine Air Ground Task Force Training Command (MAGTFTC), Twentynine Palms, CA, supports natural resource management decision making. The LCTA monitoring program collects the data necessary to (1) determine effects of military activity on the current ecological condition of MAGTFTC and the trend in this condition, (2) help characterize the relationship between military impacts and the type, location, timing, intensity, and duration of training, and (3) characterize local plant communities. This report assesses the strengths and weaknesses of the current LCTA program and offers recommendations for improvements.

The LCTA program has yielded a valuable initial data set, especially for a selected area of the installation, but the plant communities over the entire installation need better sampling distribution. The complexity of the sampling can be reduced without adversely affecting the results. The analyses and reporting of the results of the initial data collection would be greatly strengthened by including more direct statistical comparisons and by increasing quality control during data collection. The overall program is good and the full value of the LCTA program will increase with each year of data collection, which will, in turn, pay dividends in its value to management decision making.

**15. SUBJECT TERMS**

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|---|---|---|
| Land Condition Trend Analysis (LCTA) | natural resource management | desert ecology, Marines |
| Twentynine Palms, CA | military training, MAGTFTC | Mojave Desert, endangered species |

| 16. SECURITY CLASSIFICATION OF: a. REPORT | b. ABSTRACT | c. THIS PAGE | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| Unclassified | Unclassified | Unclassified | SAR | 28 | Jeffrey S. Fehmi |
| | | | | | 19b. TELEPHONE NUMBER (include area code) (217) 352-6511, ext 6366 |